MCNP Simulations of Measurement of Insulation Compaction in the Cryogenic Rocket Fuel Tanks at Kennedy Space Center by Fast/Thermal Neutron Techniques

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MCNP simulations have been run to evaluate the feasibility of using a combination of fast and thermal neutrons as a nondestructive method to measure of the compaction of the perlite insulation in the liquid hydrogen and oxygen cryogenic storage tanks at John F. Kennedy Space Center (KSC). Perlite is a feldspathic volcanic rock made up of the major elements Si, Al, Na, K and O along with some water. When heated it expands from four to twenty times its original volume which makes it very useful for thermal insulation. The cryogenic tanks at Kennedy Space Center are spherical with outer diameters of 69-70 feet and lined with a layer of expanded perlite with thicknesses on the order of 120 cm. There is evidence that some of the perlite has compacted over time since the tanks were built 1965, affecting the thermal properties and possibly also the structural integrity of the tanks. With commercially available portable neutron generators it is possible to produce simultaneously fluxes of neutrons in two energy ranges: fast (14 MeV) and thermal (25 meV). The two energy ranges produce complementary information. Fast neutrons produce gamma rays by inelastic scattering, which is sensitive to Fe and O. Thermal neutrons produce gamma rays by prompt gamma neutron activation (PGNA) and this is sensitive to Si, Al, Na, K and H. The compaction of the perlite can be measured by the change in gamma ray signal strength which is proportional to the atomic number densities of the constituent elements. The MCNP simulations were made to determine the magnitude of this change. The tank wall was approximated by a 1-dimensional slab geometry with an 11/16" outer carbon steel wall, an inner stainless wall and 120 cm thick perlite zone. Runs were made for cases with expanded perlite, compacted perlite or with various void fractions. Runs were also made to simulate the effect of adding a moderator. Tallies were made for decay-time analysis from t=0 to 10 ms; total detected gamma-rays; detected gamma-rays from thermal neutron reactions d. detected gamma-rays from non-thermal neutron reactions and total detected gamma-rays as a function of depth into the annulus volume. These indicated a number of possible independent metrics of perlite compaction. For example the count rate for perlite elements increased from 3600 to 8500 cps for an increase in perlite density from 6 lbs/cf to 16.5 lbs/cf. Thus the MCNP simulations have confirmed the feasibility of using neutron methods to map the compaction of perlite in the walls of the cryogenic tanks.